Introduction to Computer Graphics

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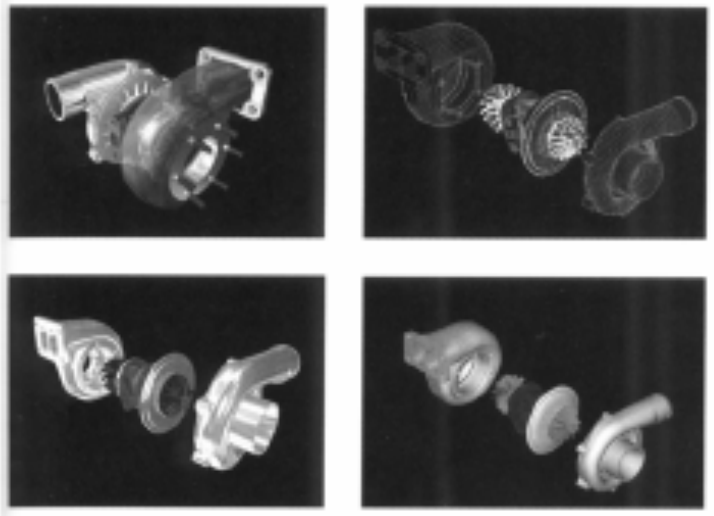
What is Computer Graphics?

Computer graphics deals with:

- Geometric modeling: creating mathematical models of 2D and 3D objects.
- Rendering: producing images given these models.
- Animation: defining/representing time dependent behavior of objects.

Applications

- Simulators (flight, driving)
- Mechanical CAD (Computer Aided Design)
- Architectural visualization
- Virtual reality Virtual reality
- Advertising

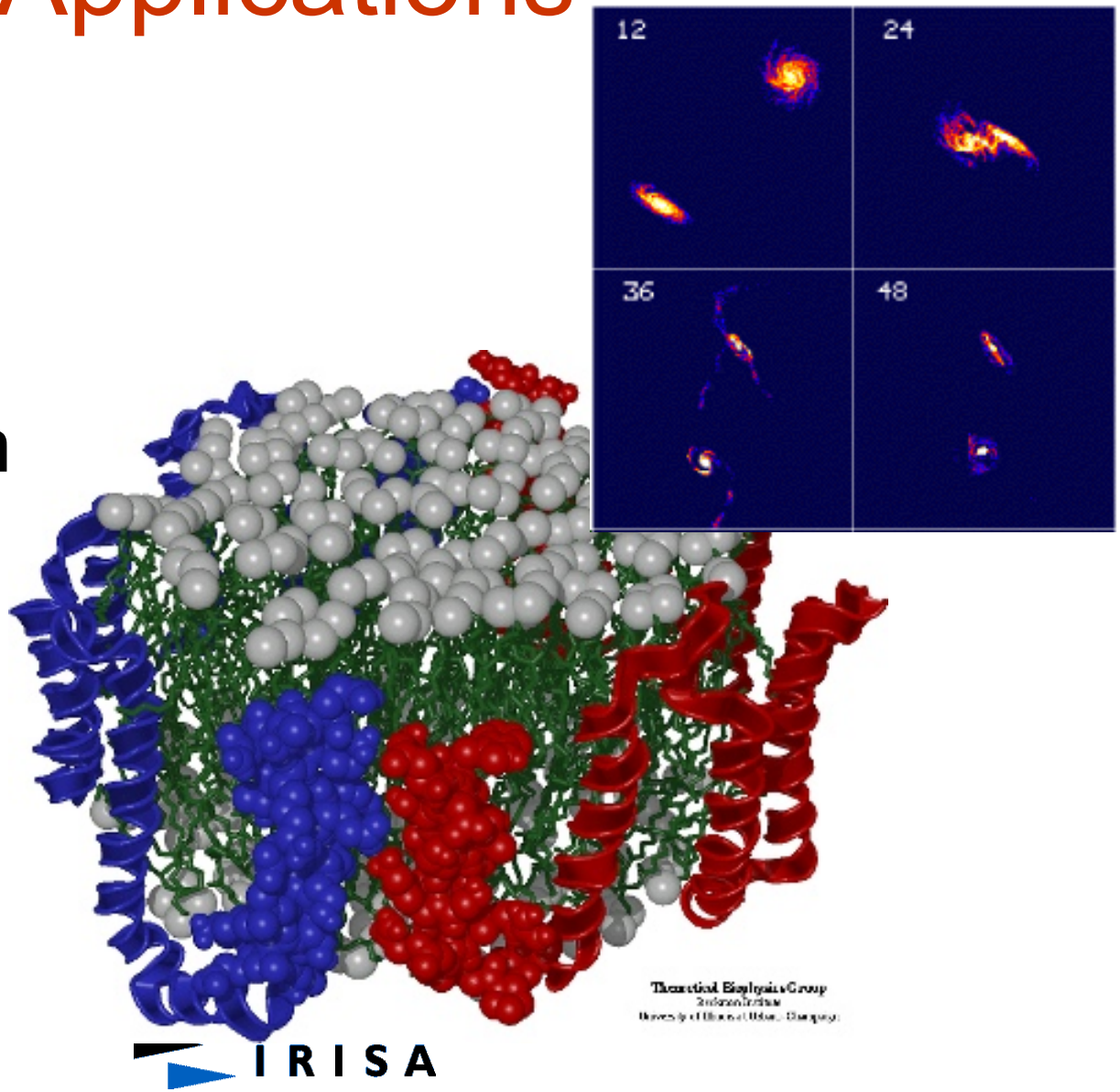


Applications

- Computer games
- Special effects
- Computer art

Applications

- Education
- Scientific visualization
- Medical imaging



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  - Rendering: producing images given these models.
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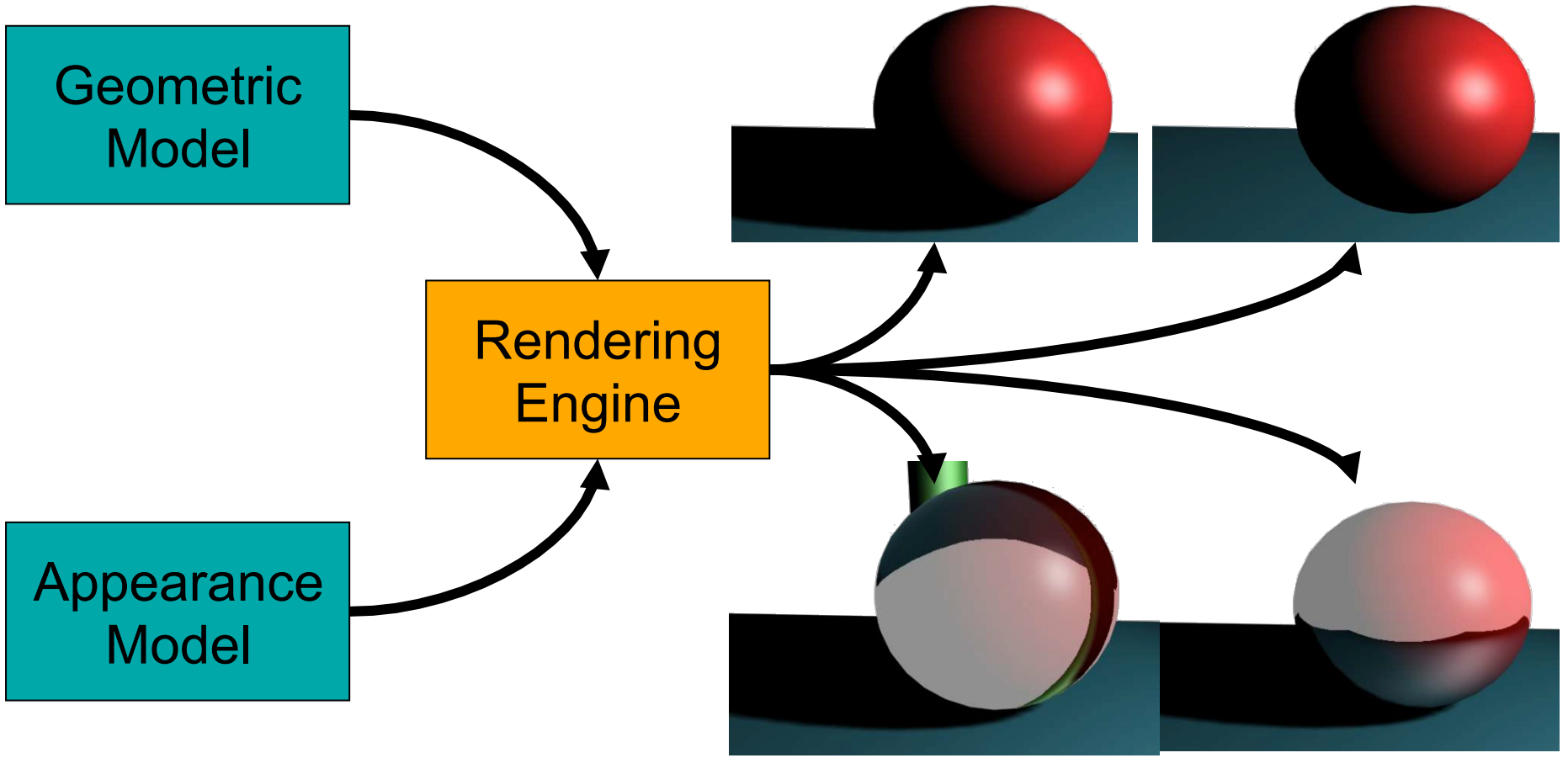
Rendering Engine



Modeling

- From a concept (or a real object) to a geometric model representable on a computer.
- Example: a sphere can be described by four real numbers: (x,y,z,r).
- Example: a polygon can be described by listing the coordinates of its vertices.

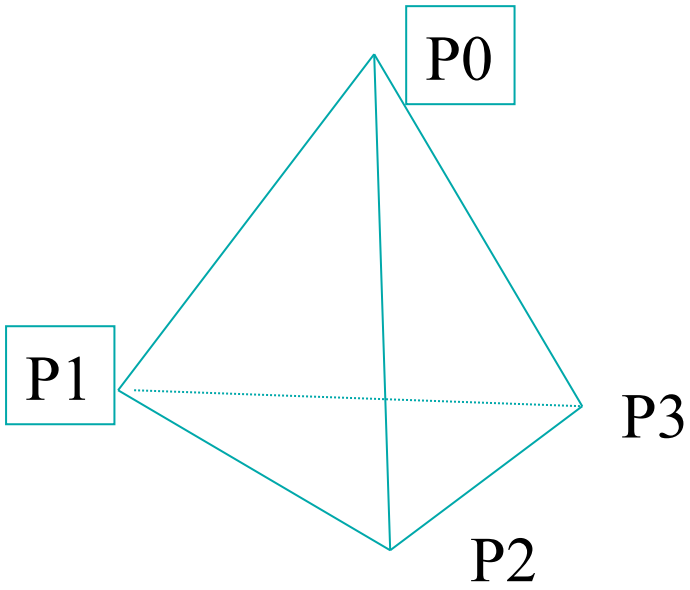
Modeling

How to represent more complex shapes?

- Polygon meshes: a large collection of polygonal facets, connected with each other.
- Free Free-form surfaces: using low-degree polynomial functions.
- CSG: construct a shape by applying boolean operations on primitive shapes.

Modeling: polygonal facets

- Facets sharing vertices
- Avoids data duplication



LS=list of vertices
LS = {P0, P1, P2, P3}
F1 = (LS [0], LS [1], LS [2])
F2 = (LS [0], LS [2], LS [3])
F3 = (LS [3], LS [1], LS [0])
F4 = (LS [3], LS [2], LS [1])
Fi = Facet i
Object = {F1, F2, F3, F4}

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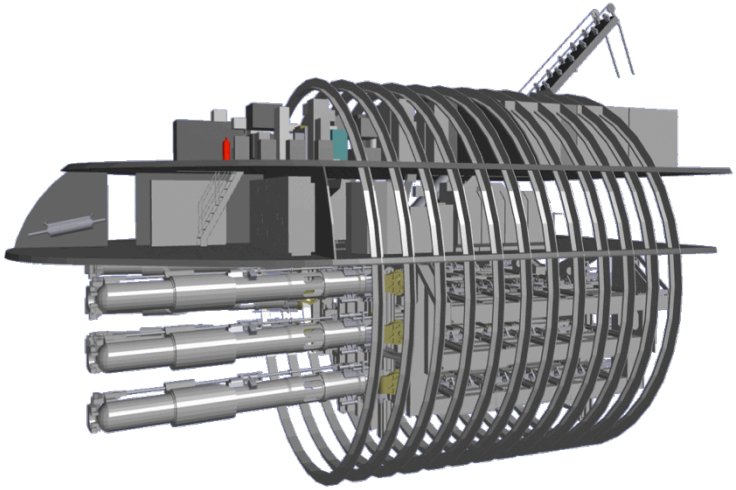
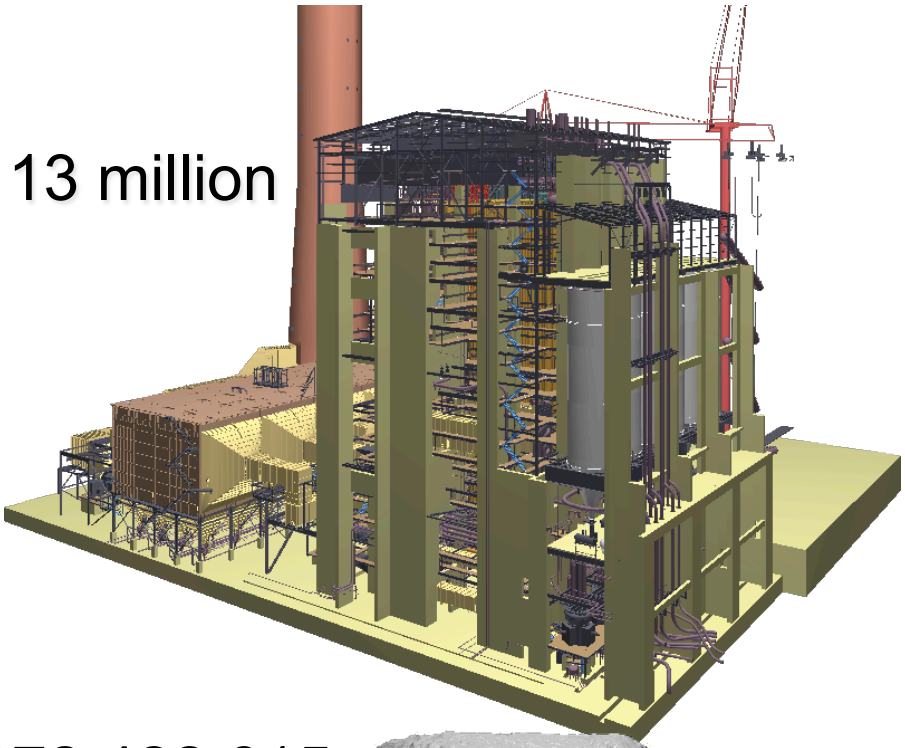
Huge models :

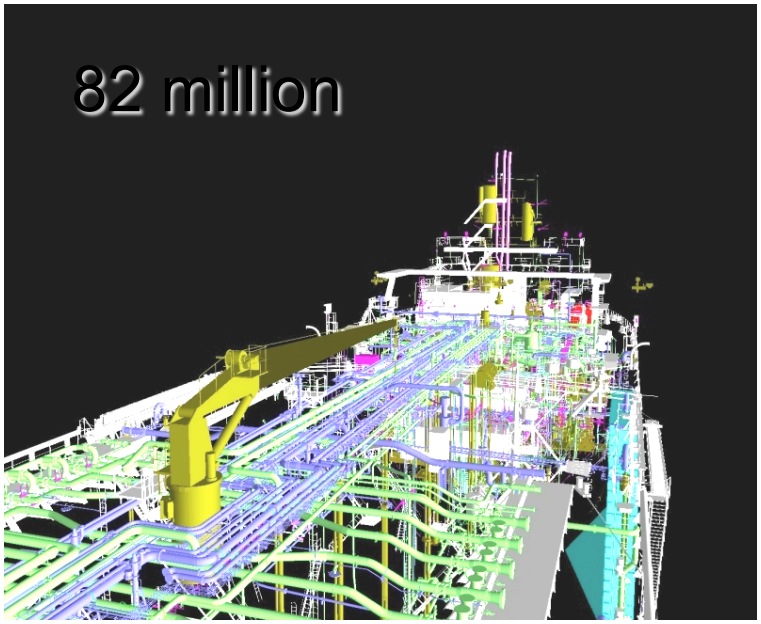
700,000



13 million



82 million



372,422,615

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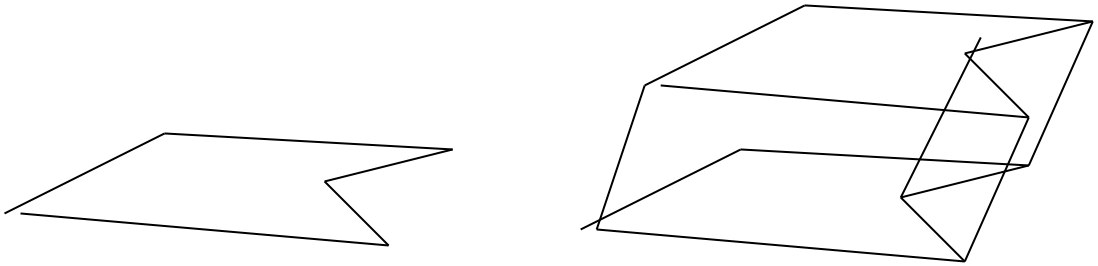
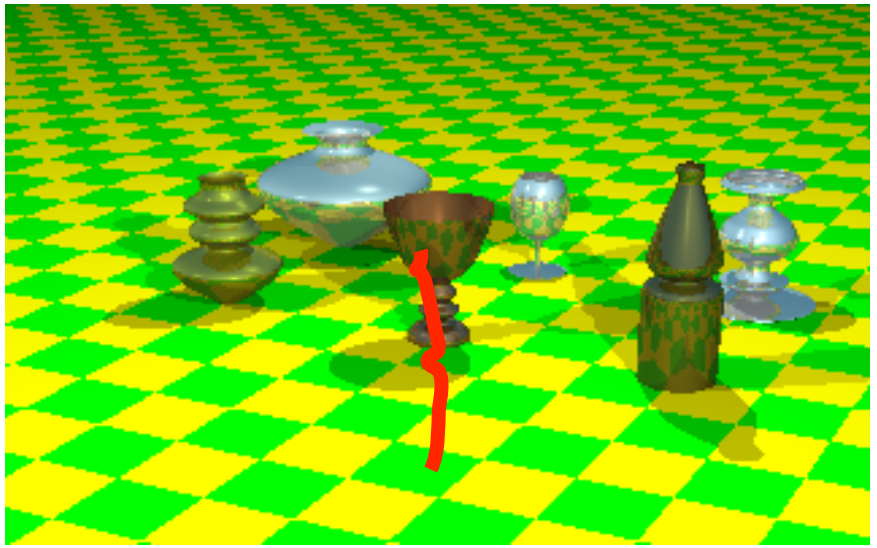
Modeling: Sweeping, revolution

- Extrusion



- Revolution



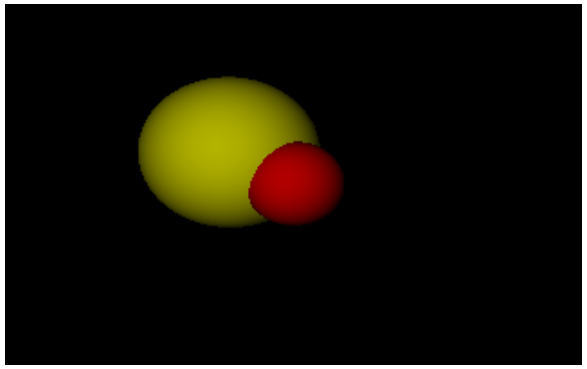
CSG Objects

- Description of complex shapes

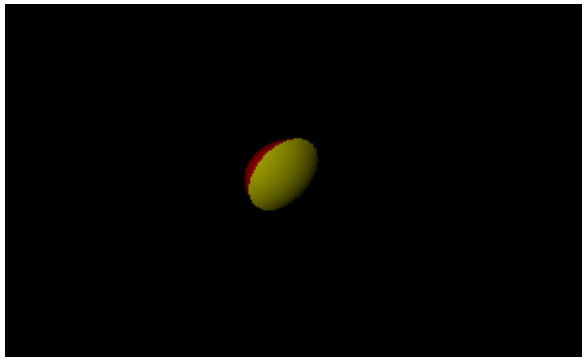
- Definition
  - Object = set of points
  - Object = sphere, cylinder, cone, box, …
  - Object = Obj1 bop Obj2
  - bop = union, intersection, difference

Modeling: CSG examples

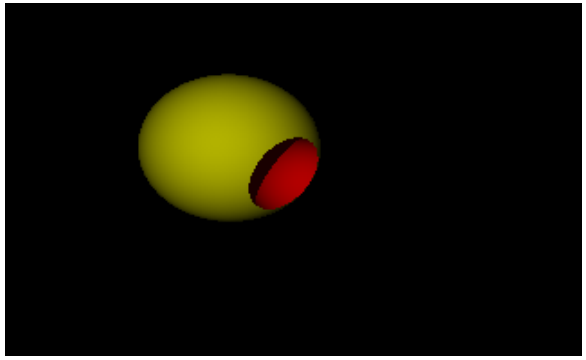
- Union



- Intersection

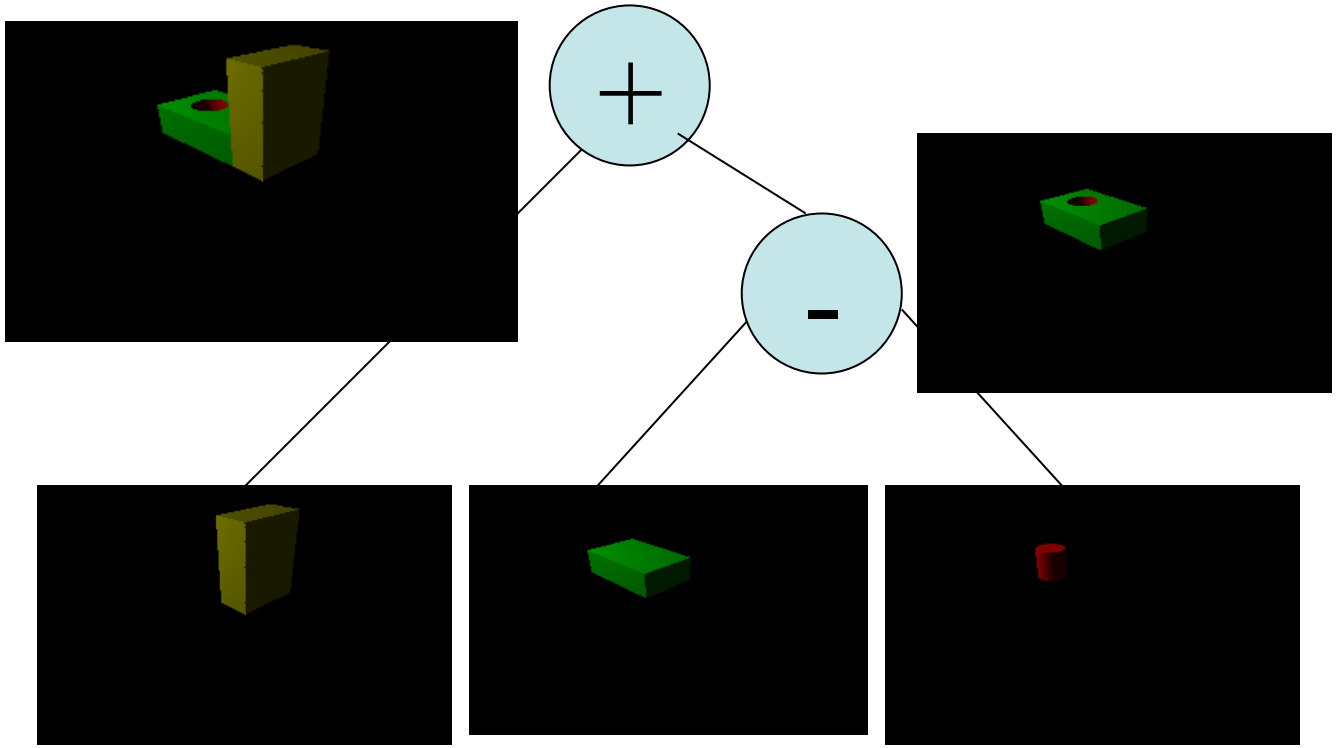


- Difference



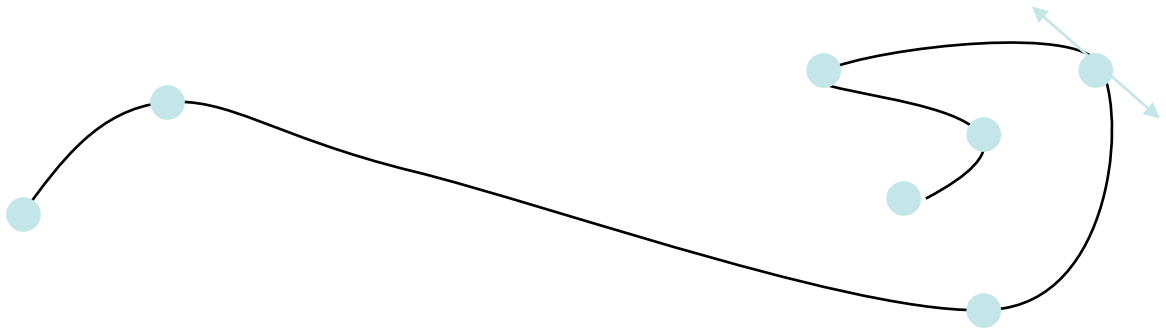
Modeling: CSG examples

- Binary tree :



Modeling: Parametric Surfaces

- Free form curves and surfaces
- Defined with control points



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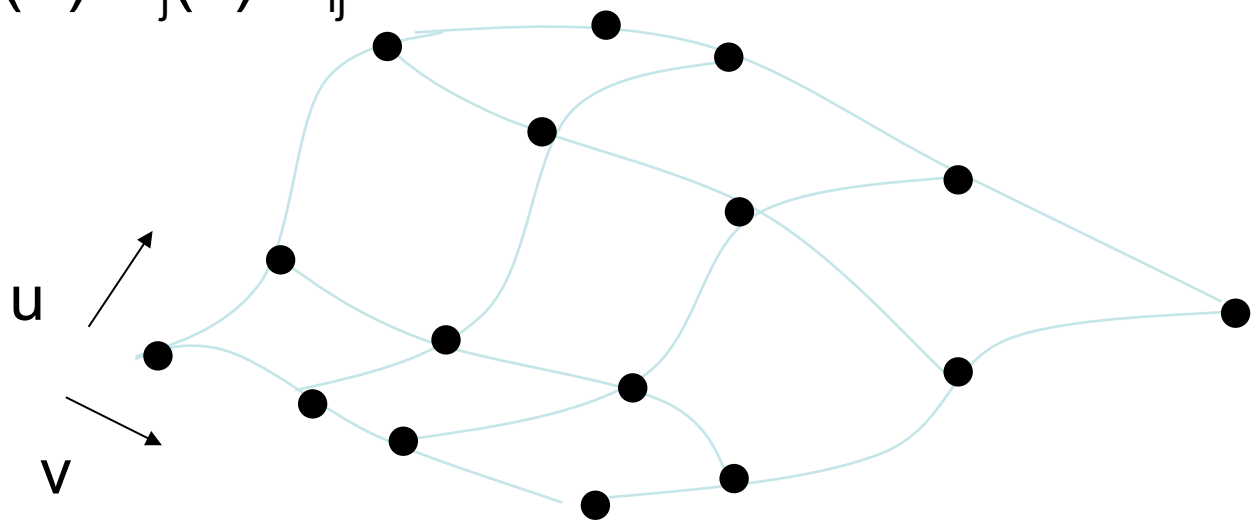
Modeling: Parametric Surfaces

Tensor product of parametric curves, functions of u and v.

$$Q(u, v) = \Sigma_{ij} B_i(u) B_j(v) V_{ij}$$



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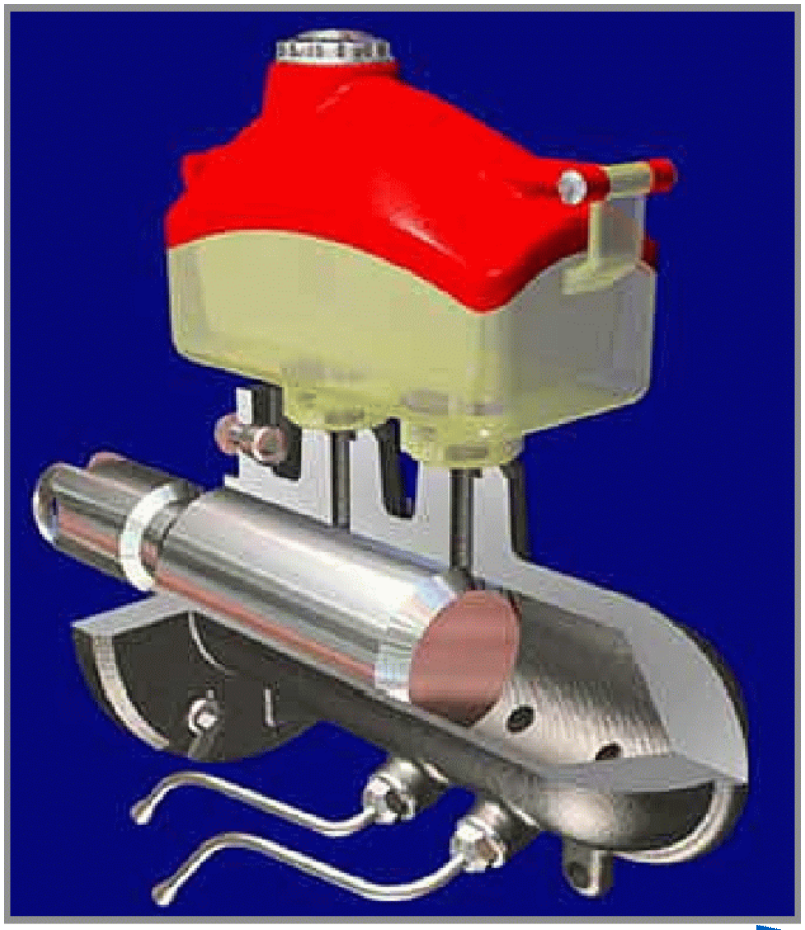
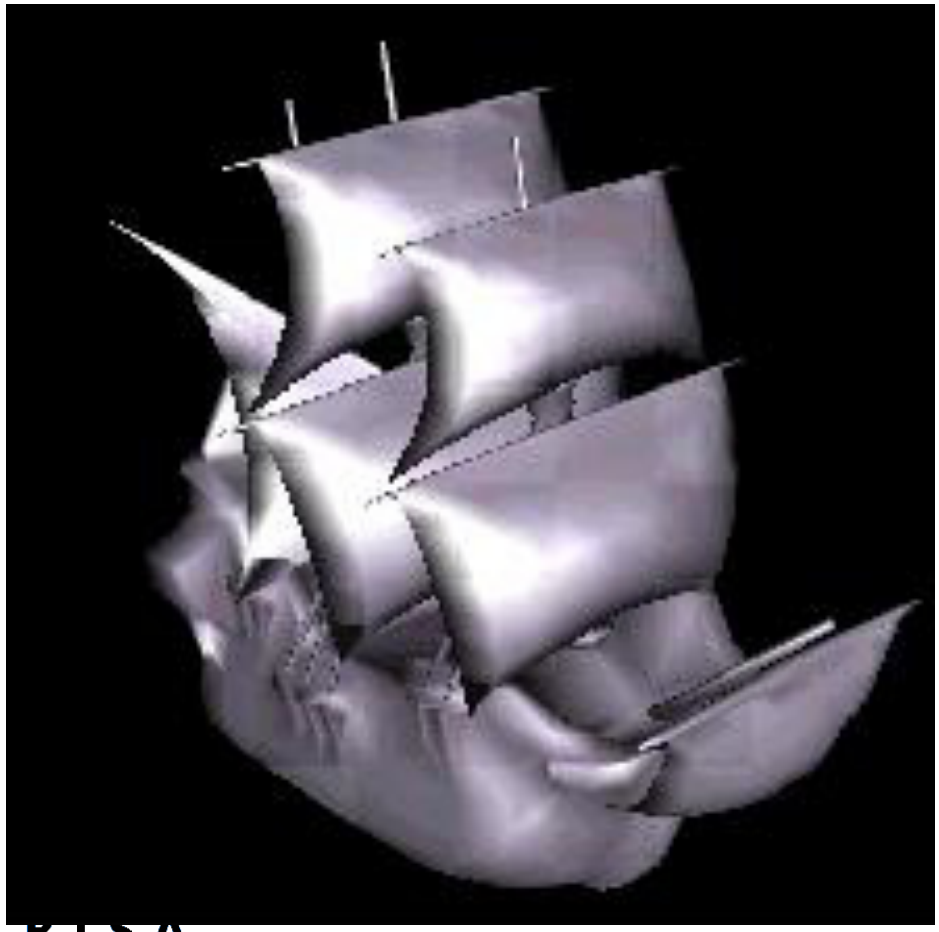
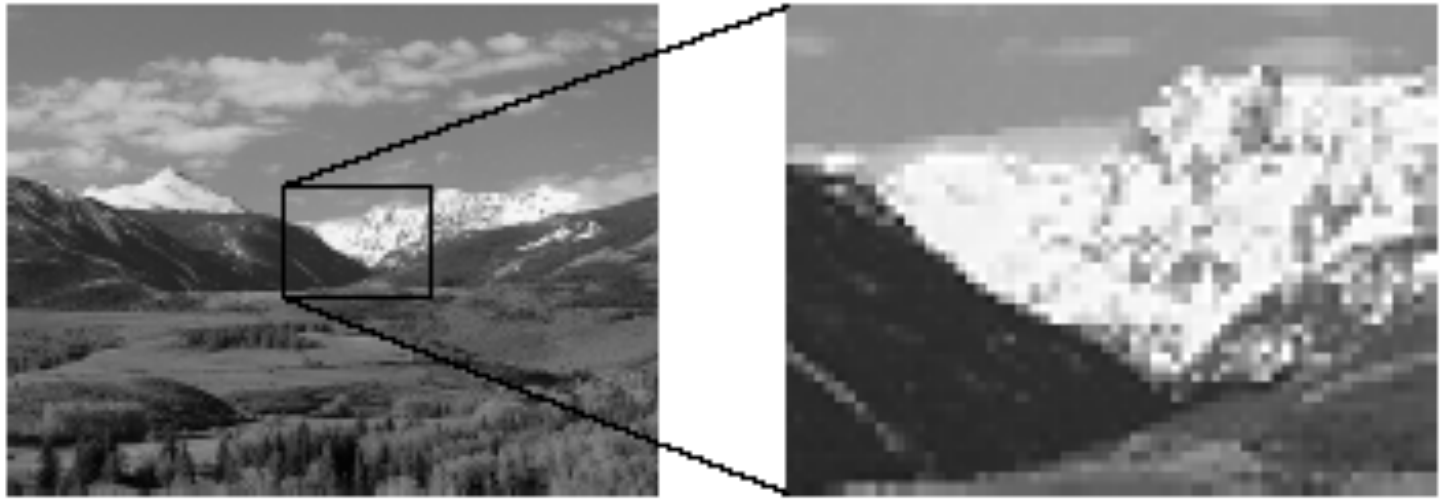
Surfaces splines





Rendering

- Given a scene and viewing parameters, produce an image = a 2D array of pixels.



Rendering

Important sub-tasks:

- Scan conversion: Which pixels in the image are covered by each object?
- Visible surface algorithms: What is visible at each pixel of the image?
- Illumination and shading: What color should be assigned to each pixel?

Animation

- How to define complex time-dependent behavior of objects?
- Examples:
  - Automatic inbetweening (interpolation key-frames).
- Physically-based simulation.

Surface Appearance

- Surface: Appearance
  - What are the properties of material?
  - How the surface reacts to light?
  - In what direction and what part of the spectra is it reflecting?
  - Is it fuzzy?
  - Is the surface bumped like metal?
  - etc.

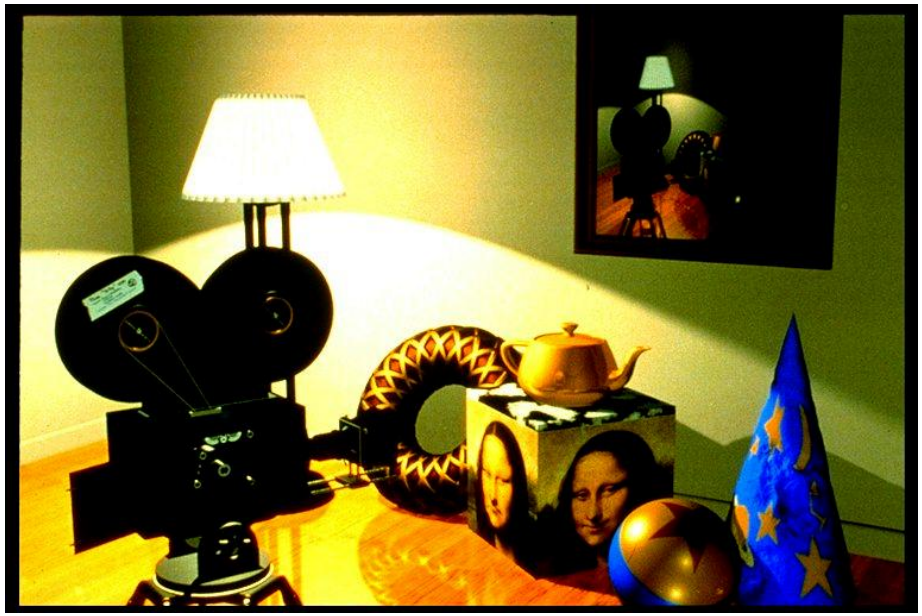
Summary

- How the image is created?
  - Put objects into the memory
  - Assign appearance and/or textures to their surfaces
  - Assign lights
  - Position camera(s)
  - Run the illumination algorithm: different techniques (scan conversion, ray tracing)
  - Display images

Context

- Image Processing: from images to images
- Computer Vision: from images to models
- Computer Graphics: from models to images

Examples of different effects



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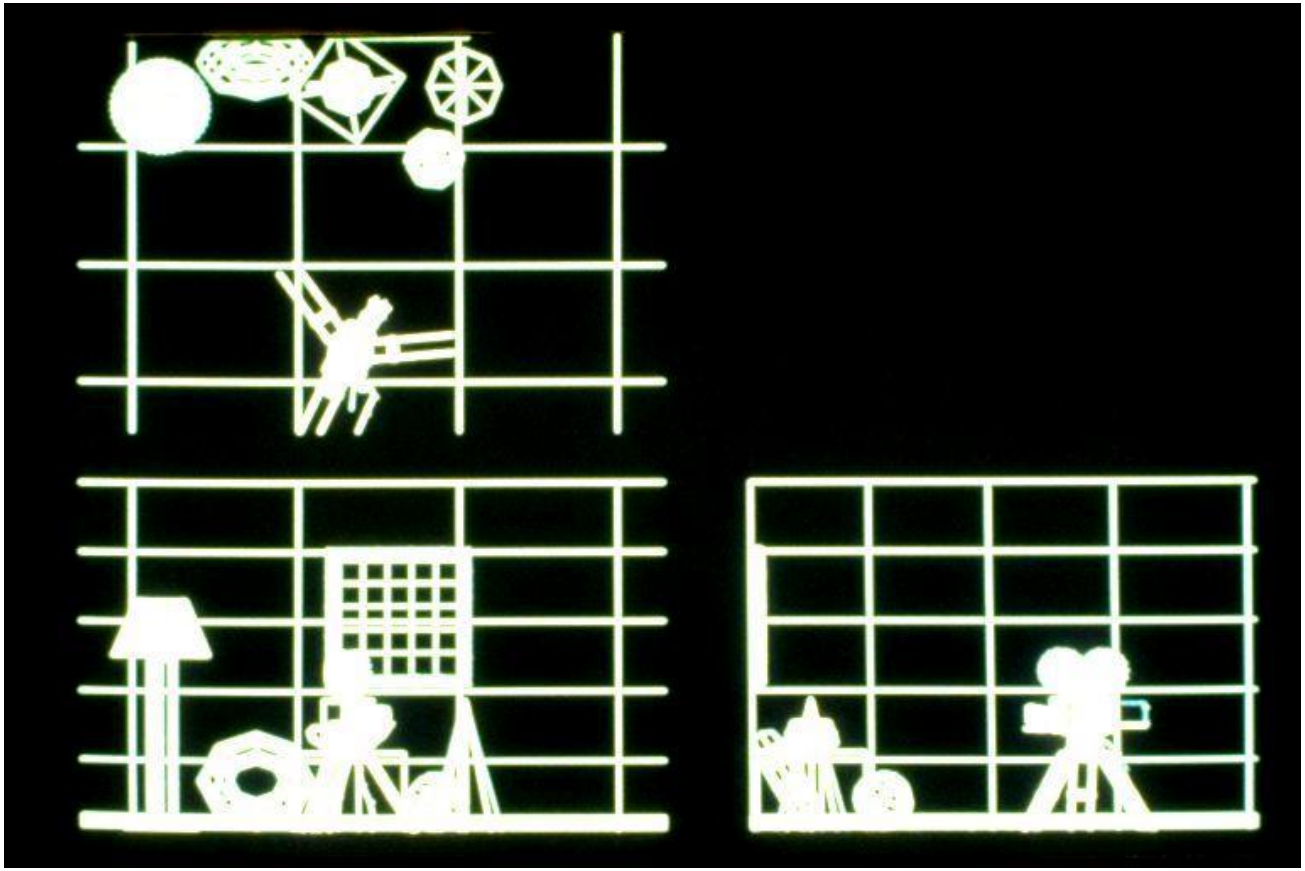
Wireframe model – Orthographic views



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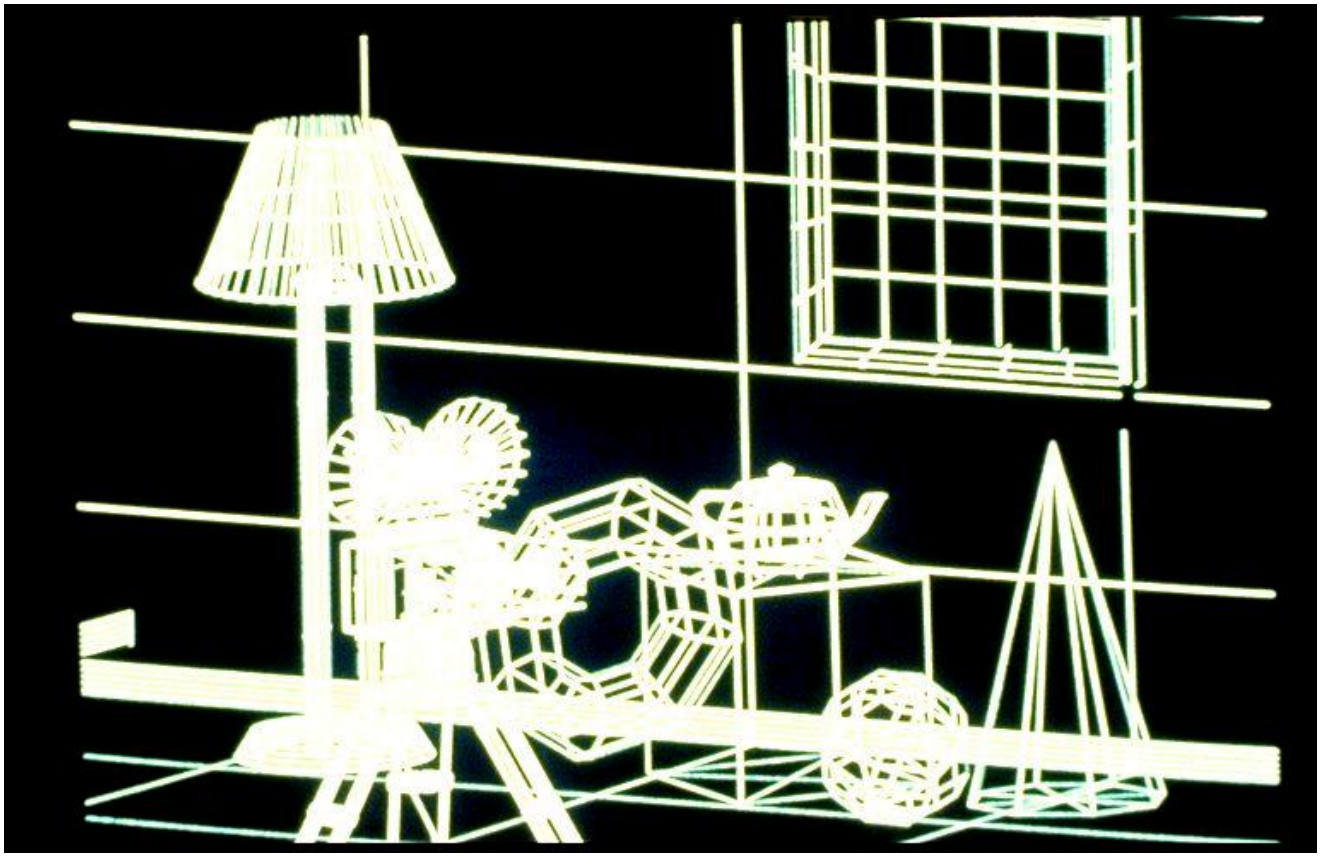
Perspective View



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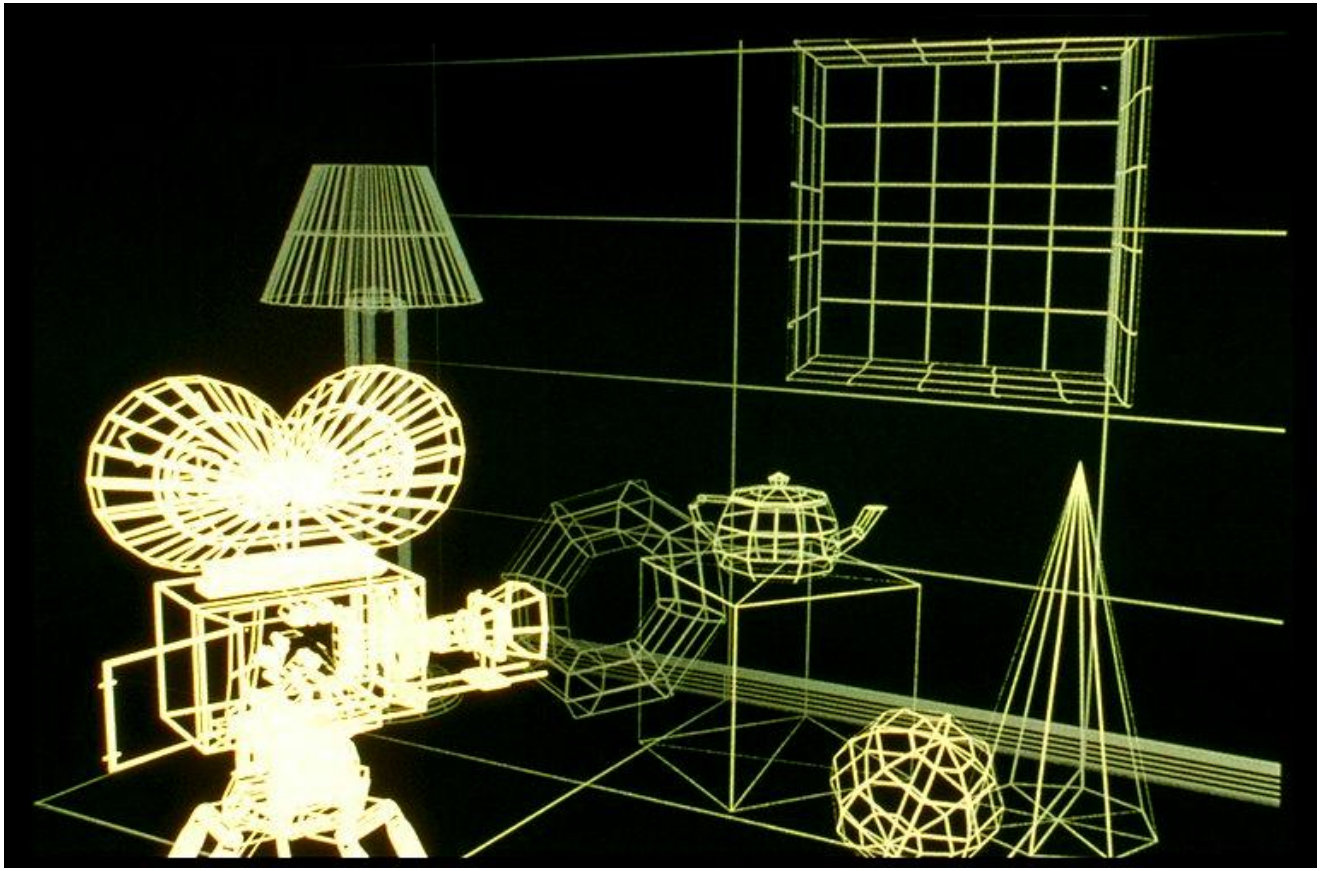
Depth Cue



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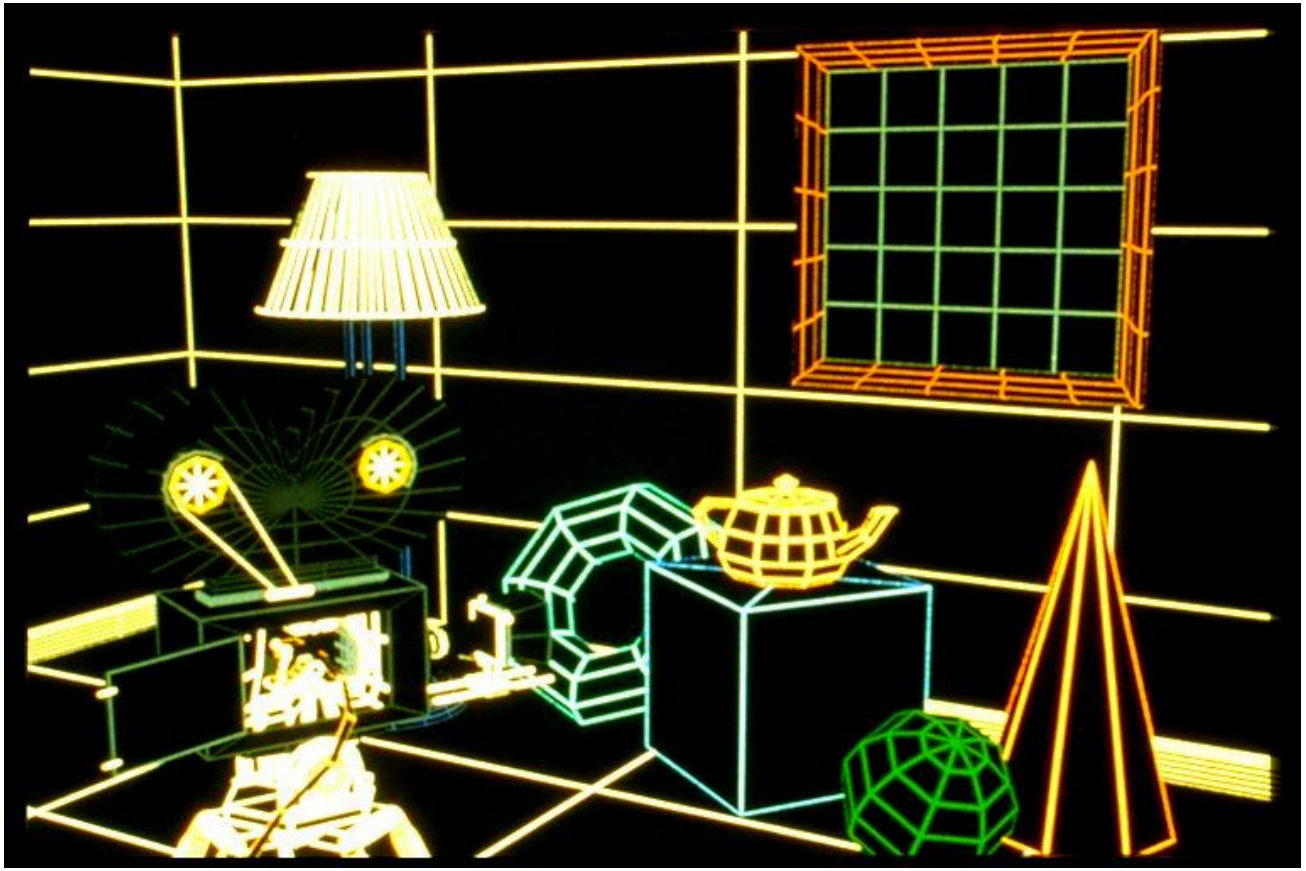
Hidden Line Removal – add colour



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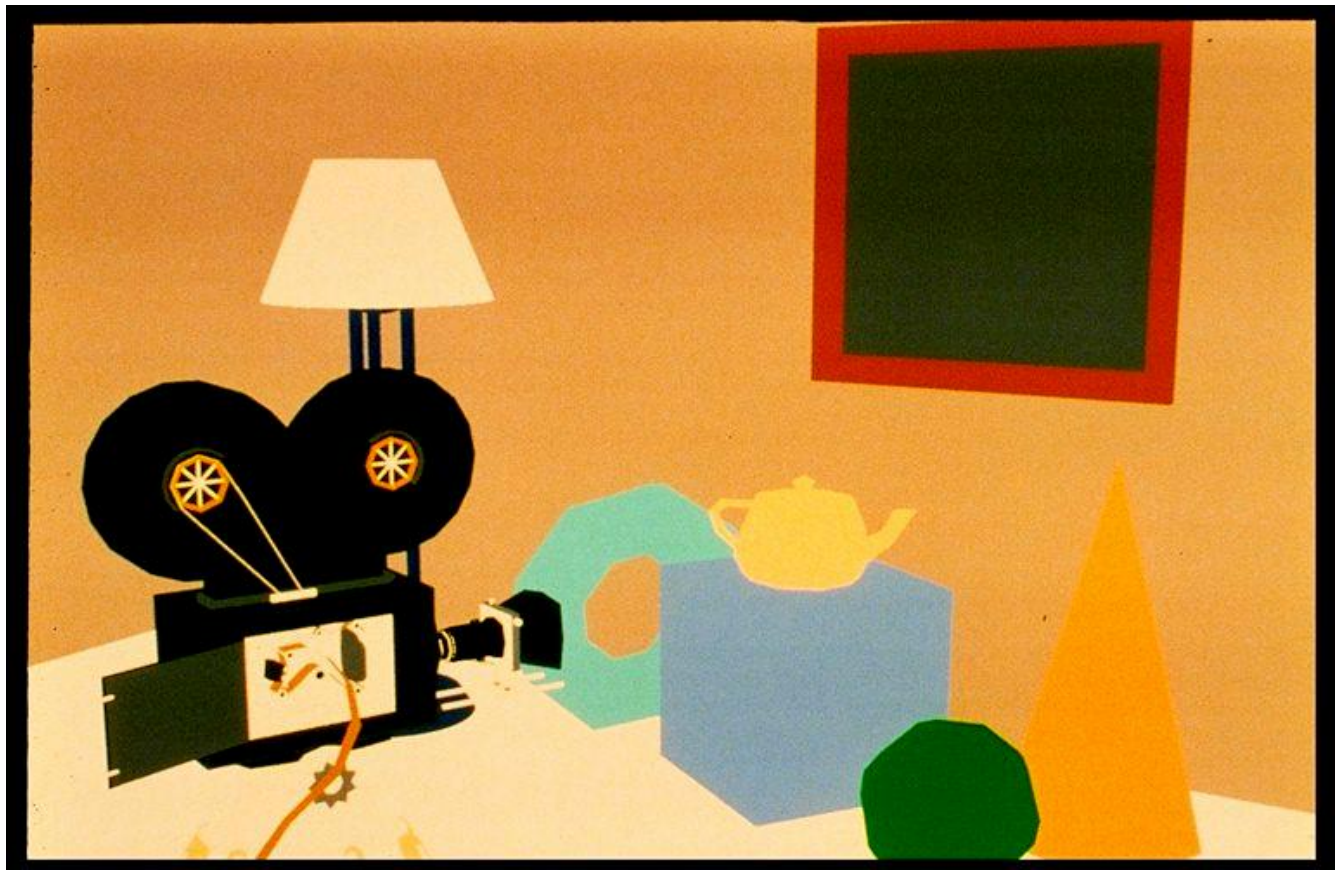
Constant Shading - Ambient



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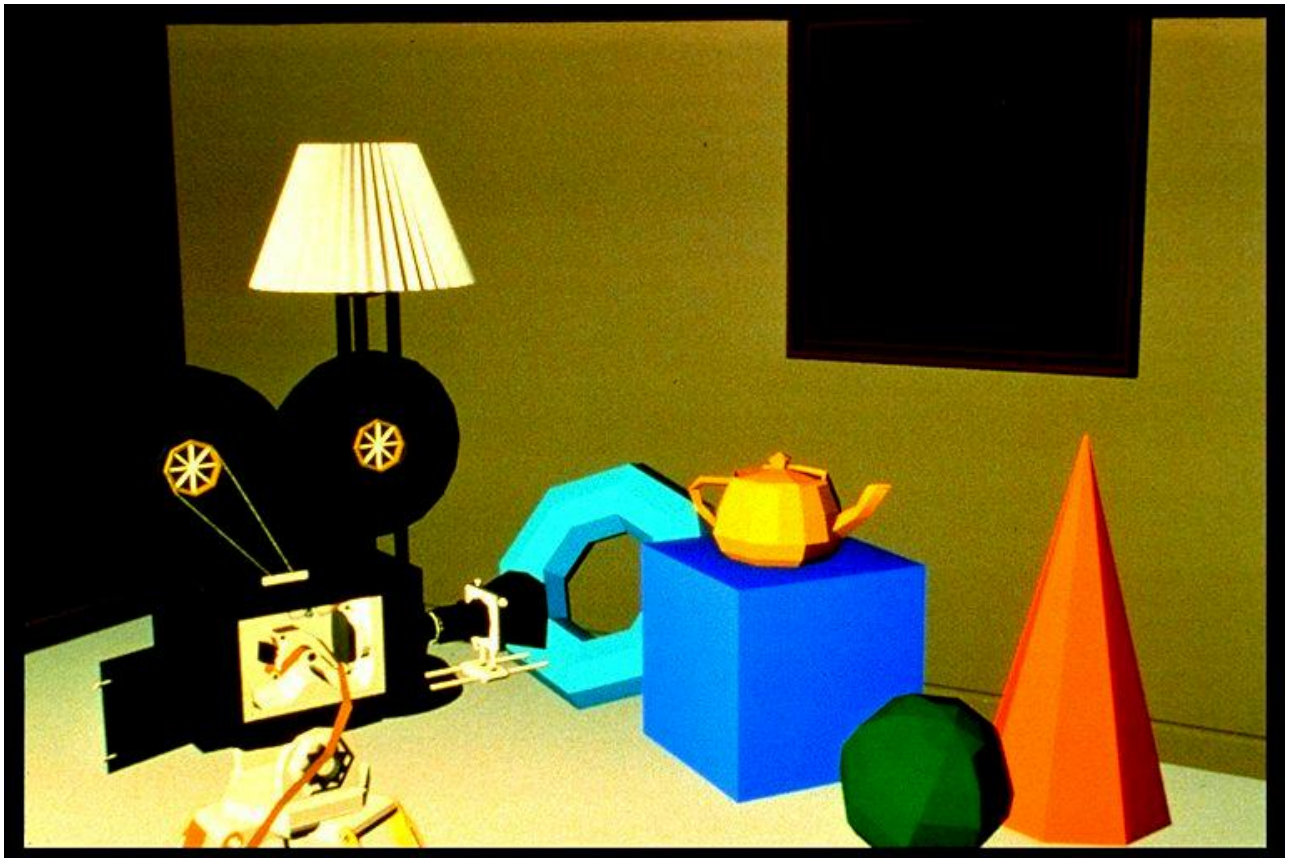
Faceted Shading - Flat



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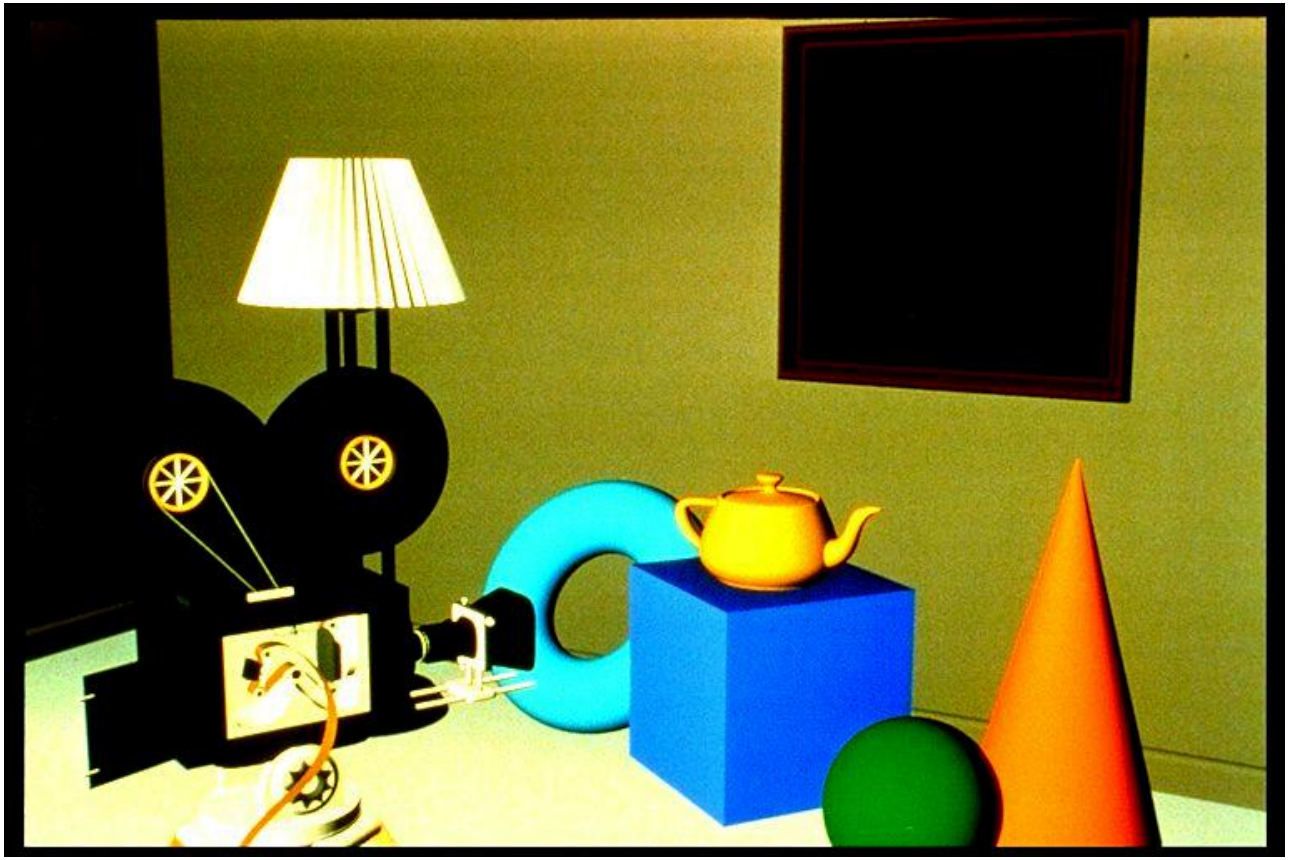
Gouraud shading, no specular highlights



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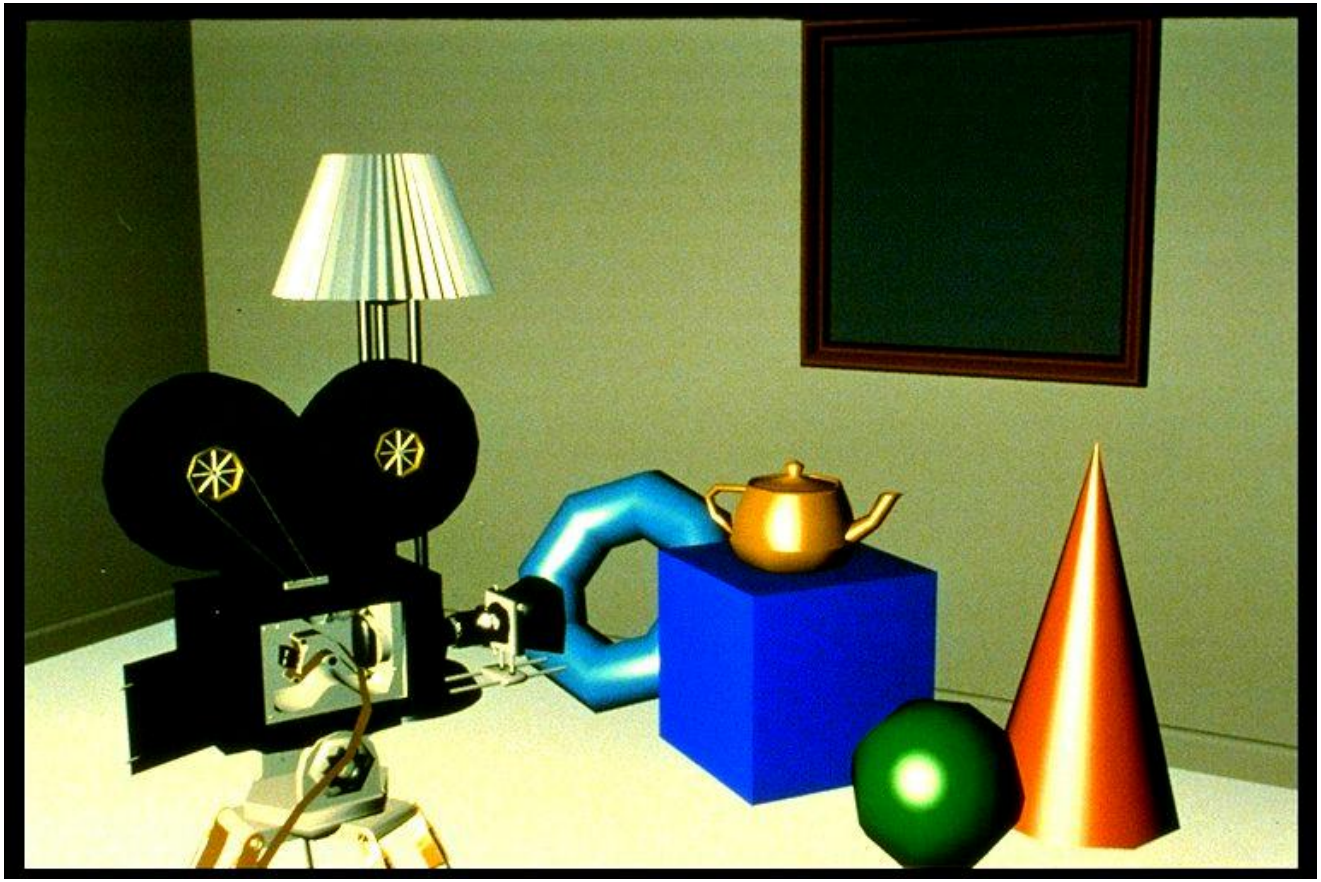
Specular highlights added



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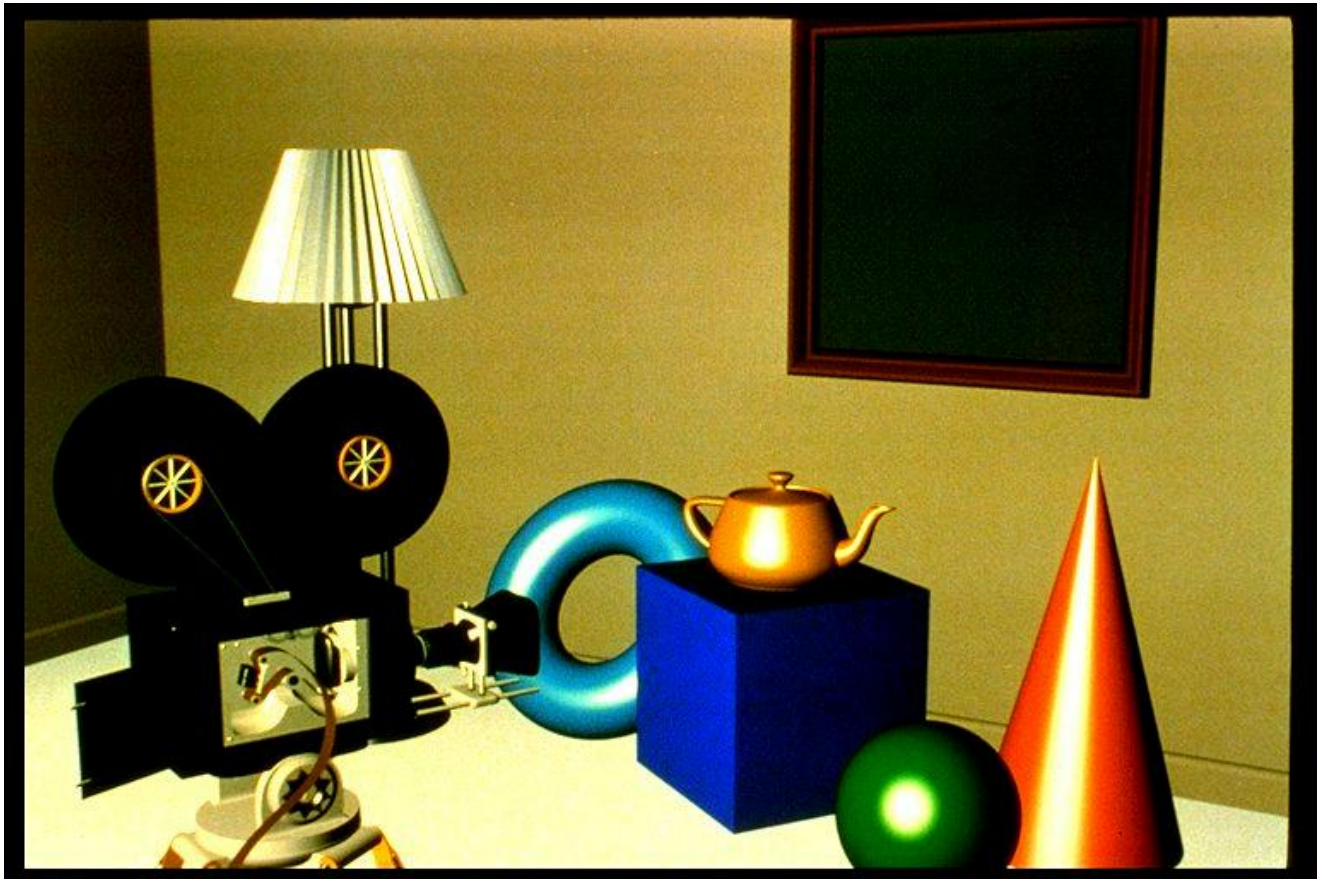
Phong shading



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Texture mapping

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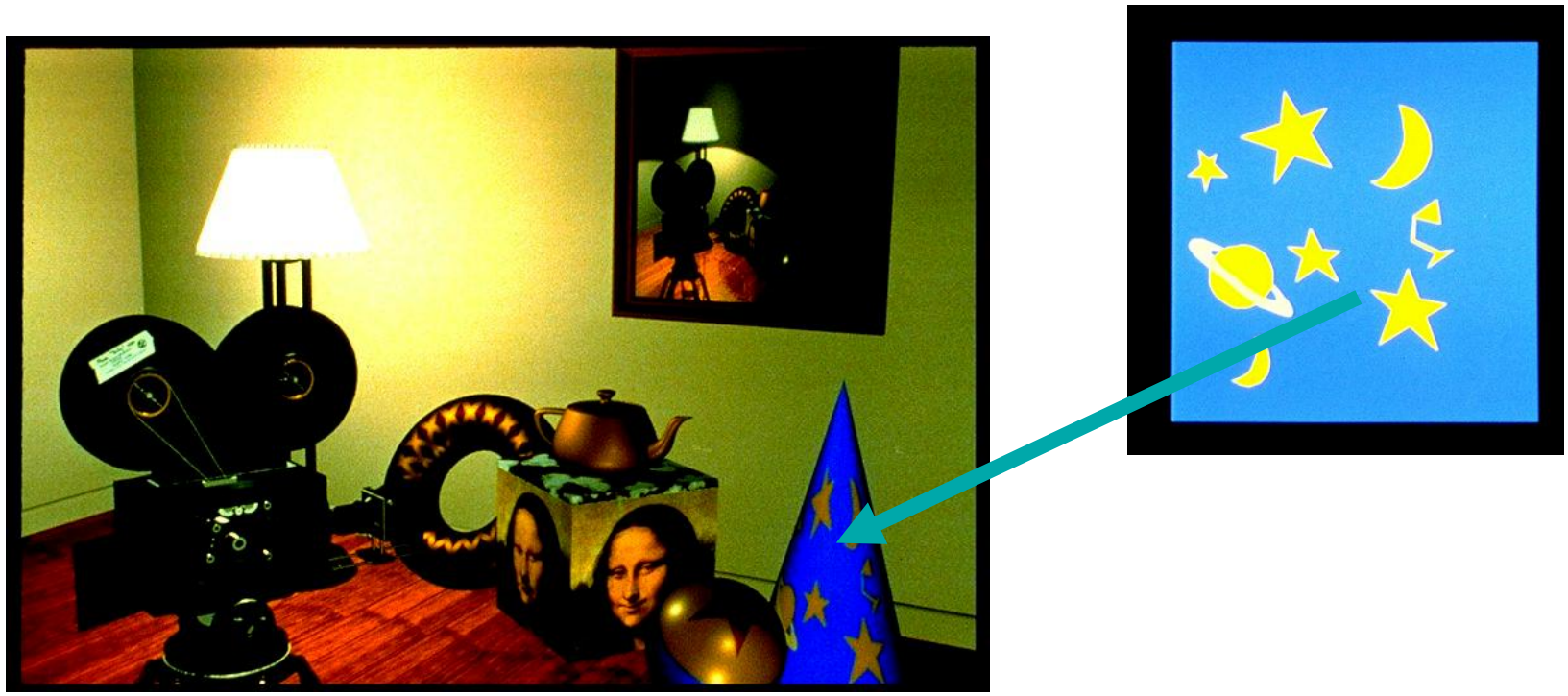
Texture mapping



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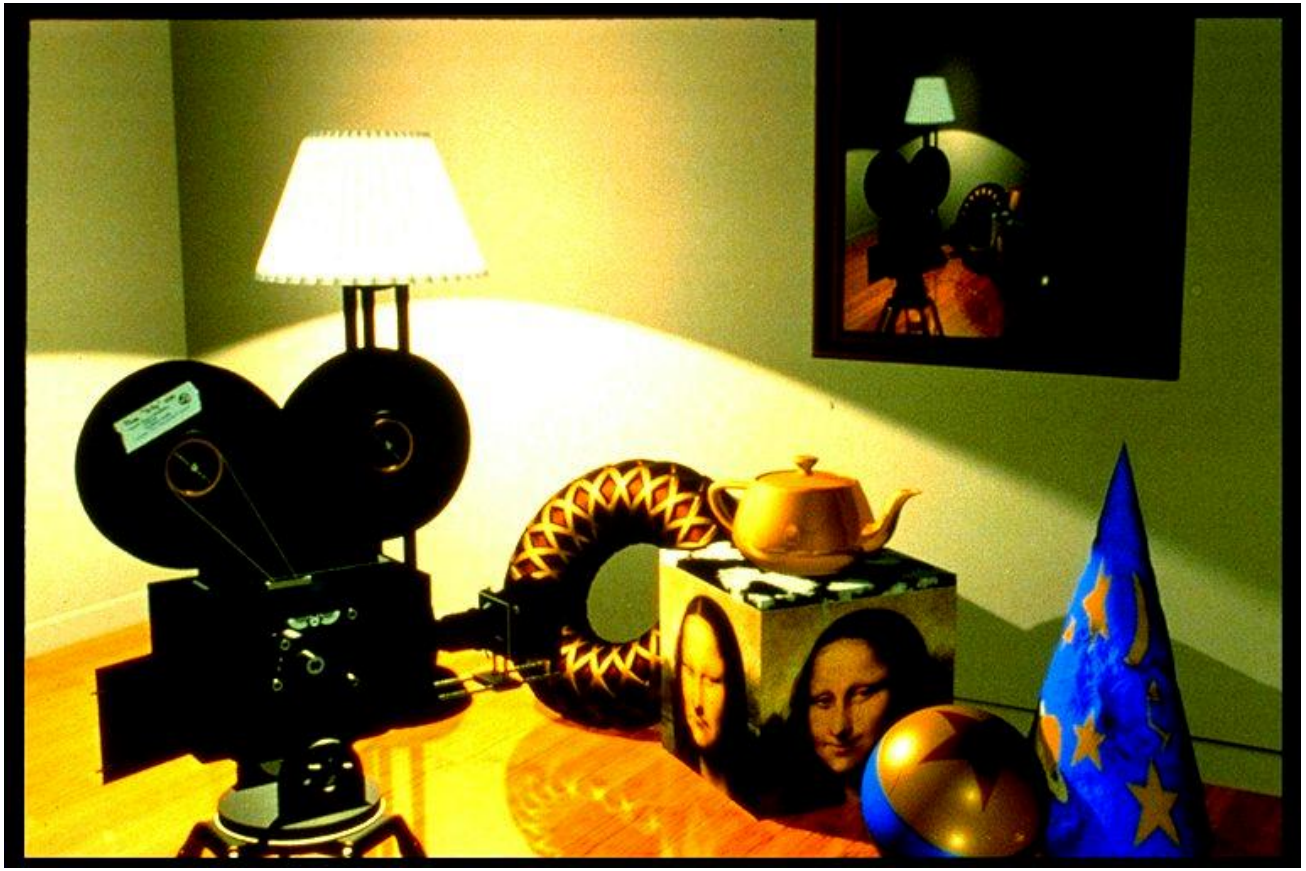
Reflections, shadows & Bump mapping



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